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Sustainable Agriculture in Assam: Issues and Solutions

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Abstract: *Agriculture occupies a central position in the socio-economic life of Assam. A large proportion of the state's rural population depends directly or indirectly on crop cultivation, horticulture, livestock, fisheries and plantation agriculture for income and employment. Assam possesses considerable agricultural potential because of its fertile alluvial soils, abundant rainfall, extensive river systems, diverse agro-climatic conditions and rich biological resources. Rice is the dominant food crop, while mustard, pulses, vegetables, fruits, tea and other commercial crops contribute to agricultural diversification. However, the sustainability of agriculture in Assam is increasingly threatened by climate variability, recurrent floods, waterlogging, soil degradation, limited irrigation, fragmented landholdings, inadequate mechanization, weak post-harvest infrastructure and unstable market conditions. Climate change presents a particularly important challenge. Recent empirical research using data from 2000 to 2022 found statistically significant relationships between temperature, rainfall and the productivity of rice, tea and mustard in Assam. The study estimated that a 1°C increase in temperature was associated with declines in yields of these crops, while excessive rainfall beyond crop-specific thresholds reduced productivity, particularly in rice because of waterlogging.*

Keywords: *Sustainable agriculture, Assam, climate change, agriculture, rice, tea, organic farming, soil health.*

1. INTRODUCTION

Agriculture is one of the most important sectors of the economy of Assam. It provides livelihoods, food, raw materials and employment to a substantial section of the state's population. Agriculture is also deeply connected with rural culture and social organization. Traditional farming practices, rice cultivation, livestock rearing, fishing and horticulture form an important part of the livelihood systems of rural communities. Assam's agricultural environment is characterized by considerable ecological diversity. The Brahmaputra and Barak valleys contain extensive alluvial plains, while the hill districts possess different soil, rainfall and elevation conditions. The state experiences high annual rainfall, but its distribution is uneven across seasons and locations. The same water resources that provide agricultural opportunities can also create serious risks through floods, erosion and waterlogging. The Government of Assam's Directorate of Economics and Statistics publishes the *Economic Survey, Assam* and the *Statistical Handbook, Assam*, which provide important official information concerning agriculture, land use, production, irrigation and related economic indicators. These publications constitute an important statistical foundation for analyzing the state's agricultural economy. The concept of sustainable agriculture is particularly relevant in Assam because agricultural productivity cannot be considered independently of environmental conditions. Increasing production through excessive chemical inputs, inappropriate land use or unsustainable water extraction may produce short-term gains but create long-term costs. Sustainable agriculture instead seeks to maintain or improve productivity while conserving soil, water, biodiversity and other natural resources. The challenge is therefore not merely to produce more food. Assam needs an agricultural system that can simultaneously:

- Provide Adequate Food;
- Generate Stable Farmer Incomes;
- Withstand Floods and Climatic Shocks;
- Maintain Soil Fertility;
- Use Water Efficiently;
- Reduce Unnecessary Chemical Inputs;
- Conserve Biodiversity;
- Create Employment;
- Reduce Post-Harvest Losses;
- Connect Farmers with Remunerative Markets.

The importance of this transition has increased because climate change is already affecting agricultural conditions. A recent study by Bordoloi and Dutta (2025), based on Assam-specific data from 2000–2022, found significant effects of temperature and rainfall variation on rice, tea and mustard yields.

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Objectives of the Study

- To examine the importance of sustainable agriculture for Assam.
- To identify the major environmental and socio-economic challenges affecting agricultural sustainability.
- To examine the effects of climate change and climatic variability on agricultural production.
- To analyse problems associated with rice-based farming and rice-fallow areas.
- To examine soil degradation and the importance of soil-health management.

2. RESEARCH METHODOLOGY

This research uses a qualitative and analytical approach based primarily on secondary information. The study draws upon peer-reviewed academic research, official Government of Assam publications, ICAR publications and research conducted by scholars associated with Assam Agricultural University and other institutions. An important principle of the methodology is that Assam-specific evidence is preferred wherever it is available. Agricultural sustainability differs according to geography, climate, cropping patterns, markets and institutional conditions. Therefore, evidence from Assam provides greater contextual relevance than general statements about Indian agriculture. The paper uses empirical studies on climate change, soil quality, rice-fallow cropping and organic tea cultivation to support its discussion of specific problems. Government publications are used primarily for institutional and official contextual information rather than for unsupported interpretation. The Government of Assam's Directorate of Economics and Statistics currently provides the *Economic Survey, Assam 2025–26*, making it an important official source for contemporary economic context.

Concept of Sustainable Agriculture

Sustainable agriculture can be understood as a system of agricultural production that meets present needs while maintaining the ecological and productive capacity required for future generations. It differs from a purely production-oriented approach because it considers the long-term consequences of agricultural practices. Economic sustainability is one of its central dimensions. Farmers must earn sufficient and reasonably stable income from agriculture. A practice that improves soil quality but makes farming financially impossible for producers cannot easily be sustained. Similarly, a crop-diversification programme will not succeed if farmers cannot sell the crops profitably. Environmental sustainability is equally important. Agriculture depends upon soil, water, biodiversity and ecosystem services. Continuous cultivation, inappropriate fertiliser use, soil erosion, excessive water extraction and loss of biodiversity can gradually reduce the productive capacity of agricultural land. Social sustainability involves the capacity of rural communities to continue farming as a viable livelihood. It includes access to knowledge, technology, finance, markets, infrastructure and institutional support. For Assam, where many farming households operate on a relatively small scale, social and economic dimensions are particularly important. Sustainable agriculture should therefore be viewed as a balance among productivity, profitability, environmental protection and resilience.

Agriculture and Ecological Conditions in Assam

Assam's agricultural potential is closely related to its natural environment. The Brahmaputra and Barak river systems have created extensive alluvial landscapes that support agriculture. High rainfall provides water for crop production, while variations in elevation, soil and moisture create opportunities for a wide range of crops. However, agriculture is also exposed to considerable environmental variability. Rainfall may be excessive during one period and insufficient during another. Floods may submerge agricultural fields, while prolonged waterlogging can prevent subsequent cultivation. Riverbank erosion may permanently alter agricultural land. The relationship between climate and agriculture is therefore complex. Rainfall itself is not necessarily harmful. Crops require adequate rainfall, but excessive rainfall can become damaging. The study by Bordoloi and Dutta (2025) illustrates this non-linear relationship, finding that rainfall increased crop yields up to certain thresholds but that excess rainfall reduced productivity. This has important implications for agricultural planning. Sustainable agriculture in Assam cannot be based solely on increasing irrigation or increasing water availability. It must also address drainage, water storage, flood management and efficient water use. The agricultural system must consequently become more flexible and adaptable to changing environmental conditions.

Climate Change and Agricultural Sustainability

Climate change is one of the most significant long-term challenges to agriculture in Assam. Changes in temperature and rainfall can influence crop growth, flowering, maturity, pest incidence, disease pressure, soil moisture, irrigation requirements and the timing of agricultural operations. The Assam-specific study by Bordoloi and Dutta (2025) provides quantitative evidence of this relationship. Analyzing data from 2000 to 2022, the authors examined rice, tea and mustard and found that a 1℃ increase in temperature was associated with estimated yield declines of approximately 0.112 tonnes per hectare for rice, 0.087 tonnes per hectare for tea and 0.095 tonnes per hectare for mustard. The study also identified rainfall thresholds beyond which additional rainfall reduced productivity. These findings should not be interpreted as meaning that every future temperature increase will automatically produce

exactly the same yield reduction in every location. The estimates are statistical relationships derived from the study's data and models. Nevertheless, they provide important evidence that climate conditions have measurable implications for Assam's major crops. Farmers also perceive climatic changes at the local level. Buragohain and Lotha (2023) studied 120 farmers from Jorhat and Karbi Anglong and examined their perceptions of climate change and coping strategies. Their research shows that farmers are responding to climatic variability through adjustments in agricultural practices.

Floods and Waterlogging

Flooding is one of the most important environmental challenges confronting agriculture in Assam. Floods can damage standing crops, destroy seedlings, erode agricultural land, affect livestock, damage agricultural infrastructure and disrupt transport and markets. The agricultural consequences of flooding depend on its timing, duration, depth and location. A short period of inundation may be tolerated by some crops, while prolonged waterlogging can cause severe damage. The consequences are especially serious when floods occur close to harvesting. Waterlogging also creates a secondary problem. Even after floodwaters recede, soils may remain saturated for extended periods. Farmers may then be unable to plant a subsequent crop within the available agricultural season. This is particularly relevant to rice-based systems. Bordoloi and Dutta (2025) specifically identify waterlogging as one mechanism through which excessive rainfall can reduce rice productivity. Sustainable agriculture must therefore incorporate flood and waterlogging management into cropping decisions. The objective should not be to eliminate every flood-related risk, which may be unrealistic, but to design agricultural systems capable of reducing losses and recovering more quickly after climatic shocks.

Climate-Resilient Agriculture

Climate-resilient agriculture involves adjusting agricultural production systems so that they can maintain productivity under changing climatic conditions. In Assam, this can involve several complementary strategies. The first is the use of crop varieties appropriate to local climatic risks. Flood-tolerant or short-duration varieties can be useful in areas where crop calendars are frequently disrupted. The choice of variety should, however, be based on local conditions and scientific recommendations rather than on a universal assumption that one variety will solve all climate-related problems. The second strategy is adjustment of crop calendars. If rainfall patterns change, sowing and harvesting dates may need to change accordingly. Farmers require reliable weather information and extension support to make such decisions effectively. The third strategy is diversification. Dependence on a single crop exposes households to concentrated production risk. A combination of crops with different climate sensitivities can reduce the likelihood of complete agricultural failure. Finally, climate resilience requires infrastructure. Drainage, irrigation, storage, roads, livestock shelters and post-harvest facilities can all influence how effectively farmers respond to climate shocks.

Soil Degradation and Soil Health

Soil is the fundamental productive resource of agriculture. Sustainable agriculture therefore requires maintaining soil fertility, structure, organic matter, biological activity and nutrient availability. A 2025 study by Chakravarty, Nath and Sarma examined soil quality in rice-based systems in Nalbari district, Assam, using a Relative Soil Quality Index. The researchers compared rice-fallow and rice-oilseed systems with adjacent uncultivated soils. They found evidence that continuous cultivation without appropriate soil-management practices shifted good-quality soils toward medium-quality categories. The significance of this research extends beyond Nalbari. It illustrates a broader principle of agricultural sustainability: increases in cropping intensity must be accompanied by appropriate management of soil resources. If nutrients are removed through repeated crop harvests without adequate replenishment, soil quality can decline. Similarly, continuous cultivation without sufficient organic-matter management may affect soil structure and biological activity. Sustainable soil management therefore requires a combination of soil testing, balanced fertilization, organic matter management, crop rotation, residue management and appropriate tillage practices.

3. SUSTAINABLE NUTRIENT MANAGEMENT

Nutrients are essential for crop production, but sustainable agriculture requires their efficient and balanced use. Both nutrient deficiency and excessive nutrient application can create problems. Soil testing can help identify nutrient requirements and reduce unnecessary input expenditure. Farmers can then apply fertilizers according to crop requirements and soil conditions. Organic sources such as farmyard manure, compost, green manure and suitable crop residues can contribute to soil organic matter. Their effectiveness depends on quality, availability, timing and appropriate application. Legume crops can also contribute to diversified nutrient management systems. Integrating pulses and other legumes into cropping sequences can improve system diversity while providing additional food or income. The aim should therefore not be to eliminate fertilizers completely but to develop integrated nutrient management, in which mineral and organic nutrient sources are used efficiently according to local soil and crop conditions.

Rice Mono-cropping and Crop Diversification

Rice is fundamental to food security in Assam, but excessive dependence on rice mono-cropping can create environmental and economic limitations. Continuous rice production can place pressure on soil resources and may limit the opportunity to cultivate other crops. Crop diversification provides a way of increasing the economic and ecological resilience of agricultural systems. Depending on local conditions, farmers may cultivate mustard, pulses, potato, pea, vegetables, fruits, spices, fodder crops, or other suitable crops. Research in Assam provides evidence that alternative post-rice crops can be productive in appropriate conditions. Singh et al. (2014) evaluated potato, pea and mustard in hydric rice-growing soils of the upper Brahmaputra Valley and examined their economic efficiency under different management levels. Diversification can provide several benefits. It can increase cropping intensity, spread economic risk, improve the utilization of residual soil moisture, provide additional food and income and reduce dependence on a single commodity. However, diversification should be location-specific. Farmers should not be encouraged to grow a crop merely because it is profitable somewhere else. Soil, water, flood duration, market access, labour, seed availability and local consumer demand must all be considered.

Irrigation and Water Management

Water management is a complex issue in Assam because the state experiences both excess water and periods of inadequate agricultural moisture. High annual rainfall does not guarantee that water will be available at the precise time required by crops. Agricultural sustainability therefore requires more than conventional irrigation expansion. It requires integrated management of rainfall, surface water, groundwater, and drainage and soil moisture. Rainwater harvesting can help capture water during periods of excess rainfall for later use. Small-scale irrigation can support crops during dry periods. At the same time, drainage systems are necessary in areas vulnerable to prolonged waterlogging. Water-management systems should be adapted to local conditions. A low-lying flood-prone field may require drainage and flood-resilient crops, whereas an upland field may benefit more from supplementary irrigation and moisture conservation. The central principle should be efficient and locally appropriate water management rather than simply increasing water availability.

Organic Agriculture in Assam

Organic agriculture has potential in Assam because of the state's agricultural diversity and growing interest in environmentally sustainable production. Organic practices can reduce reliance on synthetic agricultural inputs and may contribute to soil and ecosystem management. However, organic agriculture should not be considered automatically sustainable in every situation. Sustainability depends on productivity, resource use, labour requirements, markets, certification and profitability. Farmers converting to organic systems may face transition-related challenges. If yields decline temporarily and there is no price premium, the economic incentive for conversion may be weak. For organic agriculture to become sustainable, therefore, farmers require more than certification. They need access to appropriate organic inputs, technical knowledge, quality control, processing facilities, branding and reliable markets. Organic production should consequently be promoted through complete value chains rather than isolated production programmers.

Sustainable Tea Cultivation

Tea is a particularly important example of the relationship between agriculture, environment, employment and markets in Assam. The tea industry has a long history in the state and small-scale tea growers have become an increasingly important part of tea production. Tea cultivation can create economic opportunities, but intensive production may also involve substantial use of fertilizers and pesticides. Sustainable tea cultivation therefore requires attention to soil health, pest management, water resources, labour conditions and economic viability. The sustainability of tea cultivation is also strongly influenced by climate. Research has identified relationships between climatic conditions and tea productivity in Assam. The recent study by Bordoloi and Dutta (2025) found a statistically significant relationship between temperature and tea yield, while identifying excessive rainfall as another potential source of productivity loss. Climate-resilient tea production therefore requires attention to shade management, soil conservation, water management, pest and disease management and appropriate planting and farm-management practices.

Major Solutions for Sustainable Agriculture in Assam

- **Promoting Climate-Smart Agriculture:** Climate-smart agriculture should become a central component of Assam's agricultural strategy. Farmers need access to varieties and production practices suited to changing temperature and rainfall patterns. The need for such measures is supported by Assam-specific empirical evidence showing relationships between climate variables and crop productivity. Climate-smart agriculture should combine crop improvement, water management, soil conservation, weather information, crop diversification and risk management.
- **Expanding Crop Diversification:** Crop diversification should be promoted according to local agro-ecological and market conditions. Rice should remain an important component of Assam's food system, but additional crops can be incorporated where appropriate. Mustard, pulses, vegetables, potato, pea, fruits,

spices and fodder crops can contribute to diversified systems. Research on the upper Brahmaputra Valley demonstrates that potato, pea and mustard can be evaluated as post-rice crops under suitable conditions. Diversification should therefore be treated as a strategy for both economic resilience and resource management.

- **Improving Rice-Fallow Utilization:** Suitable rice-fallow areas should be identified and supported for second-season cultivation. Farmers require timely seeds, suitable short-duration varieties, moisture-management practices, machinery, extension support and access to markets. The objective should not be to cultivate every rice-fallow field regardless of environmental conditions. Instead, only technically and economically suitable areas should be intensified.
- **Protecting Soil Health:** Soil-health management should become an integral component of sustainable agriculture. Farmers should be encouraged to undertake soil testing and apply nutrients according to crop and soil requirements. Organic matter management, crop rotation, green manuring, appropriate residue management and balanced fertilization should be promoted. The Nalbari research demonstrates the importance of soil management for maintaining agricultural productivity over time.
- **Strengthening Flood-Resilient Agriculture:** Flood resilience requires a combination of crop selection, drainage, infrastructure, early warning, livestock protection and post-flood recovery. Agricultural planning should consider flood duration and depth when recommending crops and cropping sequences. Raised cultivation structures, flood-tolerant varieties, improved drainage, elevated storage and community-based disaster preparedness can reduce vulnerability where technically appropriate.
- **Developing Sustainable Water Management:** Water policy should address both scarcity and excess. Rainwater harvesting, small irrigation systems, efficient irrigation, drainage, farm ponds and water-conservation practices should be combined according to local conditions. Water management should also protect groundwater resources and avoid encouraging unsustainable extraction.
- **Supporting Organic Agriculture:** Organic agriculture should be promoted where ecological and market conditions make it viable. Farmers require support with certification, technical training, organic inputs, market access, processing and branding. Organic production should be integrated into value chains so that environmental benefits can translate into economic returns.
- **Promoting Sustainable Tea Production:** Small-scale tea growers should receive technical support for integrated pest management, soil-health management, sustainable nutrient use, water conservation and organic conversion where appropriate. The economic sustainability of organic tea research shows that stable yields and market conditions are critical to successful conversion. Therefore, policies should support both environmental sustainability and producer profitability.
- **Expanding Integrated Farming:** Integrated crop–livestock–fish systems can diversify income and improve resource recycling. Such systems are particularly relevant to smallholders because different components can support one another and reduce dependence on a single crop. Training and technical support are necessary because successful integration requires management knowledge across several agricultural activities.

Policy Framework for Sustainable Agriculture in Assam

- A long-term policy framework should begin with agro-ecological planning. Assam should not be treated as one homogeneous agricultural region. Flood-prone lowlands, upland areas, tea-growing regions, hill areas and horticultural zones have different requirements.
- The second component should be climate resilience. Agricultural planning must incorporate climate information and promote varieties and cropping systems appropriate to local climatic risks.
- The third component should be soil and water conservation. Agricultural intensification should never be separated from the maintenance of the natural resource base.
- The fourth component should be economic diversification. Farmers should have opportunities to combine food crops, oilseeds, pulses, horticulture, livestock, fisheries and other activities.
- The fifth component should be value-chain development. Production increases alone cannot guarantee higher incomes. Farmers need access to storage, processing, transportation, branding and markets.
- The sixth component should be institutional development. FPOs, cooperatives, extension agencies, agricultural universities, research organizations and government departments should work together.
- Finally, policy evaluation should consider not only production but also farm income, soil quality, water use, climate resilience, resource efficiency and environmental outcomes.

4. CONCLUSION

Sustainable agriculture is one of the most important requirements for the long-term development of Assam. The state has considerable agricultural advantages, including fertile soils, abundant water resources, diverse agro-climatic conditions, rich biodiversity and a long tradition of farming. Yet these advantages are accompanied by serious vulnerabilities. Floods, waterlogging, climate change, soil degradation, limited irrigation, fragmented holdings, inadequate mechanization, weak value chains and market uncertainty threaten the long-term sustainability of agricultural livelihoods. Climate change makes the situation more urgent. Assam-specific research demonstrates

that changing temperature and rainfall patterns are already associated with changes in the productivity of important crops including rice, tea and mustard. The response should therefore involve a transition from conventional production-oriented agriculture toward resilient, diversified and resource-efficient agricultural systems. Crop diversification can reduce dependence on rice mono-cropping. Rice-fallow intensification can increase land-use efficiency. Soil-health management can protect the productive foundation of agriculture. Integrated farming can recycle resources and diversify incomes. Organic and low-input agriculture can contribute to environmental sustainability when supported by appropriate markets. Sustainable tea cultivation can improve the ecological performance of an important commercial crop while creating new opportunities for small growers. Assam can move toward such a system by combining its rich agricultural traditions with modern scientific research, climate information, appropriate technology and strong farmer institutions. Sustainable agriculture should consequently become not merely an environmental policy objective but a central component of Assam's rural-development strategy.

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